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(71) Applicant (for all designated States except US): ELECTRO SCIENTIFIC INDUSTRIES. INC. [US/US]: 13900 Northwest Science Park Drive. Portland. OR 97229-5497 (US).

(72) Inventors: and
(75) Inventors/Applicants (for US only) : SUN. Yunlong [CN/US]; 21708 Southwest Kristin Court. Aloha. OR 97006 (US). HUTCHENS. Craig. Dean [US/US]; 15470 Southwest 155th Court. Beaverton. OR 97007 (US).

(74) Agent: LEVINE. Michael. L.: Stoel Rives Boley Jones & Grey. 900 SW Fifth Avenue. Suite 2300. Portland. OR 97204-1268 (US).

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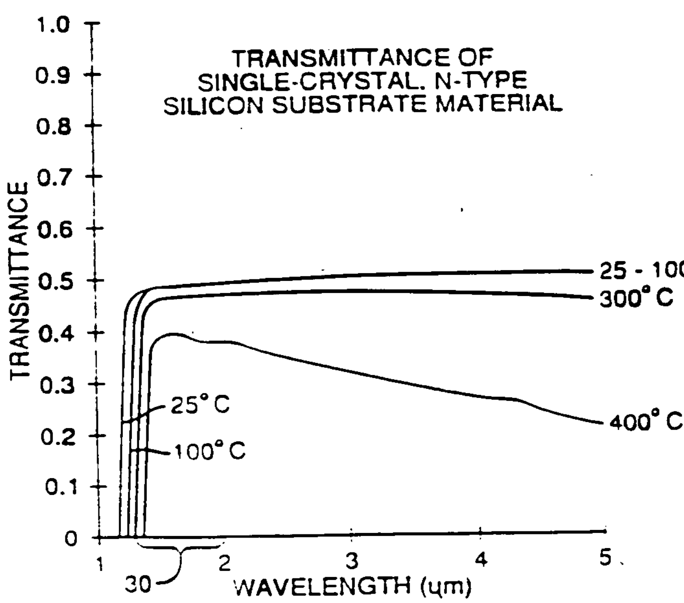

(57) Abstract

A laser system and processing method exploits the absorption contrast between the materials from which a link (12) or film and an underlying substrate (22) are made to effectively remove the link or film from the substrate. Laser output in a wavelength range of 1.2 to 2.0 μm (30) optimizes the absorption contrast between many high conductivity materials (e.g., metals) or resistive films and silicon substrates and permits the use of laser output in a wider range of energy or power levels. pulse widths. without risking damage to the silicon substrates or adjacent circuit structures. Existing link or film processing laser systems can be readily modified to operate in the 1.2 to 3.0 μm range. The laser system and processing method also exploits a wavelength range in which functional or active dedicated devices. having light-sensitive or photo-electronic portions integrated into their circuits. can be effectively trimmed without inducing malfunctions or function shifts in the processed devices.

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SYSTEM AND METHOD FOR SELECTIVELY LASER PROCESSING A TARGET STRUCTURE OF MATERIALS OF A MULTIMATERIAL, MULTILAYER DEVICE

Technical Field

The present invention relates to laser systems and methods for selectively processing a material of a single or multiple layer structure of a multimaterial, multilayer device and, in particular, to laser systems and processing methods that employ an output within a wavelength range that facilitates selective removal of an electrically conductive link or resistive film structure on a silicon substrate of an integrated circuit, as well as facilitates functional laser processing of active or dedicated devices that are sensitive to a certain spectrum of light.

Background of the Invention

Conventional laser systems are typically employed for processing target structures such as electrically conductive semiconductor link or resistive film structures in integrated circuits or memory devices such as EPROMs, DRAMs, and SRAMs. Link processing, which is presented herein only by way of example of selective material processing, may include total or partial removal, cutting, or vaporization of the link material. Examples of link processing laser systems include model Nos. 8000C

and 9000 manufactured by Electro Scientific Industries, Inc., which is the assignee of the present invention. Examples of resistive film trimming and functional device trimming laser systems include model Nos. 44 and 4200, respectively, which are also manufactured by Electro Scientific Industries, Inc. These systems utilize output wavelengths of 1.064 μm, 1.047 μm, and 0.532 μm.

The physics and computer modeling for laser-based link processing are described in "Computer Simulation of Target Link Explosion in Programmable Redundancy for Silicon Memory," L.M. Scarfone and J.D. Chlipala, Journal of Materials Research, Vol. 1, No. 2, March/April 1986, pp. 368-81, and "Computer-Simulated Explosion of Poly-Silicide Links in Laser-Programmable Redundancy for VLSI Memory Repair," J.D. Chlipala, L.M. Scarfone, and Chih-Yuan Lu, IEEE Transactions on Electron Devices, Vol. 36, No. 6, pp. 1056-1061 (June 1989).

Figs. 1A and 1B depict a conventional output energy distribution of a laser output or pulse 10 directed at an integrated circuit or memory link structure 12, which can be positioned between link terminators 14, and is typically covered by a protective layer 16 often the result of oxide passivation. Link structure 12 may be composed of one or more layers of a single material or a composite "sandwich" of several materials including those required for anti-reflective coating, binding, or other manufacturing purposes. For example, link structure 12 may include sublayers of titanium and tungsten to enhance adhesion between aluminum base link material and a silicon substrate 22 which may include oxide layers.

With reference to Figs. 1A and 1B, Chlipala et al. suggest that a laser pulse 10 focused to a spot 1 of radius R (which is, for example, about 2 μm) and applied across link structure 12 should have a suitable duration

or pulse width and be of sufficient energy at a certain wavelength to cause a temperature distribution capable of cutting link structure 12. Since the spatial or critical dimensions of spot 18 are typically (but not always) larger than the width (which is, for example, about 1 μm) of link structure 12, a portion of laser pulse 10 impinges on silicon substrate 22. Laser pulse 10 must, therefore, be tailored not to have energy sufficient to damage silicon substrate 22 or adjacent circuit structures 20 either by direct laser energy absorption, by residual pulse energy coupled into substrate 22 below link structure 12 after it is vaporized, or by thermal conduction.

Yields of memory devices, for example, have been dramatically improved by combining the use of 1.064 or 1.047 μm laser output with the use of polysilicon and polycide link structures 12 to enable redundant memory cells. Even though it is a relatively poor electrical conductor, polysilicon-based material has been used to fabricate link structures 12 because it is more easily processed by laser systems generating a conventional laser output at a wavelength of 1.047 μm or 1.064 μm at energy levels that do not prohibitively damage silicon substrate 22. A laser output having well-controlled energy and power levels can generate across an entire polysilicon link structure 12 a desired temperature distribution that exceeds the melting temperature of polysilicon. Scarfone et al. attribute this advantage to the relatively large optical absorption depth of polysilicon at 1.064 μm in combination with other favorable parameters such as the mechanical strength, the thermal conductivity, and the melting and vaporization temperatures of polysilicon,

protective layer 16, substrate 22, and other materials involved.

The technology trend is, however, toward developing more complex, higher density memories having more layers and smaller link structures and memory cell dimensions. As the complexity and numbers of layers of memory devices has increased, the polysilicon-like material has typically become more deeply buried and more difficult to process using a laser. Accordingly, an expensive and time consuming process is typically employed to delicately etch away surface layers to expose the polysilicon-like structures to be processed. Another disadvantage of polysilicon-like materials is that their electrical resistance increases with smaller dimensions, and thereby restricts the operating speed of the memory cells.

Because metals have higher conductivity and are typically deposited as a top conductive layer of memory devices, manufacturers would like to switch the material of link structures 12 to metals such as, for example, aluminum, titanium, nickel, copper, tungsten, platinum, gold, metal-nitrides (e.g., titanium nitride), or other electrically conductive metal-like materials in new generations of high-density, high-speed memory chips, whose storage capacity would exceed 4 and even 16 megabits.

Unfortunately, metals and other electrically conductive materials have much shorter optical absorption depths and smaller absorption coefficients at 1.047 μm or 1.064 μm than the absorption depth and absorption coefficient of polysilicon-like structures, causing most of the 1.047 μm or 1.064 μm laser output energy to be reflected away. Consequently, the small amount of laser output energy absorbed heats only the topmost portion or

surface of a high conductivity link structure 12 such that most of the underlying volume of link structure 12 remains at a lower temperature. Thus, it is very difficult to cleanly process a high conductivity link structure 12 with the same laser output energy and power levels used to process polysilicon-like structures.

Simply increasing the laser output power level has deleterious effects on silicon substrate 22 and adjacent circuit structures 20. On the other hand, increasing the laser output pulse width, while maintaining the output power level, to allow sufficient time for thermal conduction to redistribute the heat to the underlying volume of a high conductivity link structure 12 increases the cumulative laser energy of an output pulse, thereby increasing the risk of damage to substrate 22 and circuit structure 20. Thus, some practitioners have concluded that laser systems are no longer the proper tool for processing high conductivity links and have discussed using ion beams instead ("Focused Ion Beams," Jon Orloff, Scientific American, October 1991, pp. 96-101). However, ion beam technology is still largely experimental for such applications, is very expensive, is not an automated production process, and cannot easily be retrofit into existing laser-based link cutting systems.

Passive trimming of thin film resistor structures (not shown) in integrated circuits devices on silicon wafers is another example of selective material processing. The resistor structures typically comprise thin films of nickel chromide, tantalum nitride, cesium silicide, or other resistive materials that are embedded within or layered upon a substrate of a different material, such as silicon, and may be laser processed or trimmed to provide resistor structures with desired values. As with laser link processing, laser output that

employs conventional wavelengths and has sufficient power to insure clean trimming of resistive films on silicon substrates imposes some risk of damage to the substrate.

"Functional" laser processing or trimming of active dedicated devices is yet another example of selective material processing. In functional trimming, a dedicated device is repeatedly trimmed and evaluated until it performs its dedicated function. Functional trimming is described in detail in "Functional Laser Trimming: An Overview," R.H. Wagner, Proceedings of SPIE, Vol. 611, pp 12-13 (Jan. 1986) and "Functional Laser Trimming of Thin Film Resistors on Silicon ICs," M.J. Mueller and W. Mickanin, Proceedings of SPIE, Vol. 611, pp 70-83 (Jan. 1986).

Functional trimming with conventional laser outputs such as 1.064 μm, 1.047 μm, or their harmonics presents a different problem from link or film processing. These laser wavelengths can cause excessive carriers in the silicon substrate and result in malfunction of the device as a whole, making functional laser processing with these wavelengths impossible or prohibitively slow because extra time would be required to let these carriers disappear before the device will function normally. This is especially true for devices having some light-sensitive portions or photo-electronic elements such as CCD arrays integrated as part of the devices' function logic. During laser processing with conventional laser outputs, those light-sensitive or photo-electronic portions would react to the laser beam, causing the entire device to malfunction, regardless of their proximity to the laser beam. Functional laser processing or trimming of such devices, where the processing control is based upon measurement values of the devices real-time function, is impossible to perform due to the laser beam-induced

malfunctions of the devices.

Summary of the Invention

An object of the present invention is, therefore, to provide a laser system and method for cleanly processing link or film structures fabricated, respectively, from various high conductivity (e.g. metallic) or resistive materials without damaging underlying or surrounding substrate or adjacent circuit structures.

Another object of this invention is to provide such a system and method that employ selected laser output parameters to exploit the differential optical absorbance between high conductivity or resistive materials and silicon in order to reduce or eliminate damage sustained by the silicon substrate from residual laser output coupled into the silicon substrate after the link or film structure has been vaporized or processed.

Another object of this invention is to provide such a system and method that employ selected laser output parameters to exploit the differential optical absorbance between high conductivity or resistive materials and silicon in order to efficiently vaporize high conductivity link or resistive film structures without affecting the silicon substrate or adjacent structures falling within the critical dimensions of an oversized spot of the laser output.

A further object of this invention is to provide such a system and method that utilize a larger processing window, i.e., accepts a greater variation in device construction and/or allows a greater variation in laser output power and energy levels, pulse widths, and pulse repetition frequencies to accurately process link or film structures.

Still another object of this invention is to

provide such a system and method that can be relatively inexpensively retrofit into existing link or film processing laser systems.

The present invention exploits the differential absorption (also referred to as absorption contrast) between link or film material and the underlying substrate. The system and method of the present invention provide laser output (in a nonconventional range of wavelengths for link or film processing) that optimizes absorption contrast between, for example, silicon and high conductivity or resistive film materials including metals or semiconductors, and results in relatively efficient link or film processing (cutting or vaporizing) without risk of damage to the surrounding and underlying substrate material. In particular, silicon has been shown to be only slightly affected by laser output of suitable power in the 1.2-3.0 μm range, but aluminum, nickel, tungsten, platinum, and gold, as well as other metals, metal alloys such as nickel chromide, metal nitrides (e.g., titanium or tantalum nitride), and cesium silicide absorb such laser output relatively well.

Conventional laser systems and methods for processing link structures 12 or film structures have emphasized the laser power absorption and temperature distribution properties of link structure 12, whereas the present invention considers the optical transmission/absorption properties of substrate 22 as well. Conventional laser systems function primarily to control the temperature distribution within spot 18 by preferring 1.047 μm or 1.064 μm laser wavelengths over the 0.532 μm laser wavelength and manipulating the shape, including duration and power, of pulse 10 to avoid overheating substrate 22 while obtaining the highest possible uniform temperature distribution across link

structure 12. Because the present invention exploits the differential absorbance behavior of link structures 12 and substrate 22, the attention to pulse shaping can be relaxed and a pulse 10 of greater peak power and shorter duration can be used without risking damage to substrate 22.

Existing link or film processing laser systems can be relatively inexpensively modified to generate output in the 1.2 to 3.0 μm wavelength range. In addition, conventional laser devices that produce laser output within this wavelength range can be adapted for link or film processing. Available laser devices that produce output within this wavelength range are conventionally employed in fiber optic communications, medical applications, military range finding, and atmospheric pollution monitoring. Such laser systems have not, however, been used for general material processing because they are more complex and typically deliver laser output of significantly lower power or energy per pulse than, for example, a 1.064 μm Nd:YAG or a 10.6 μm CO_2 laser. The conventional wisdom in laser material processing, of maximizing laser output average or peak power with desired beam quality, reinforces the avoidance of using wavelengths that do not optimize output power. In contradistinction to the conventional wisdom, the present invention employs a laser output having a wavelength window that maximizes absorption contrast for selective material processing, even though the peak power of such laser output maybe lower than that which is conventionally available.

Another advantage of the selective material processing achieved by the present invention is that it facilitates the functional laser processing or trimming of dedicated devices or devices having some light-sensitive

or photo-electronic portions. For example, employing laser output having a wavelength greater than 1.2 μm to functionally process silicon-based devices substantially eliminates the undesirable laser-induced function shift or malfunction of the devices because the silicon-based light-sensitive or photo-electronic devices are virtually "blind" to wavelengths greater than 1.2 μm. The silicon substrate, itself, becomes almost transparent at wavelengths greater than 1.2 μm and does not exhibit an essential amount of carriers excited by a laser beam having such a wavelength. As a consequence, virtually no settling time is required and the voltage function measurements of these devices can be achieved almost concurrently without significant error.

Additional objects and advantages of the invention will be apparent from the following detailed description of a preferred embodiment thereof which proceeds with reference to the accompanying drawings.

Brief Description of the Drawings

Fig. 1A is a fragmentary cross-sectional side view of a conventional semiconductor link structure receiving a laser pulse characterized by a particular energy distribution.

Fig. 1B is a fragmentary top view of the semiconductor link structure and the laser energy distribution of Fig. 1A, together with adjacent circuit structure.

Fig. 2 shows graphical representations of optical transmission properties of silicon vs. wavelength for various silicon temperatures.

Fig. 3 shows graphical representations of the optical absorption properties of four different metals vs. wavelength.

Fig. 4 is a plan view of a preferred embodiment

of a laser system incorporating the present invention.

Detailed Description of Preferred Embodiment

Figs. 2 and 3 graphically show the optical transmittance properties of silicon and optical absorbance properties of different metals such as aluminum, nickel, tungsten, and platinum that may be used in future link structures 12. Fig. 2 is an enlarged replication of a portion of Fig. 6e-52 from D.T. Gillespie, A.L. Olsen, and L.W. Nichols, Appl. Opt., Vol. 4, p. 1488 (1965). Fig. 2 reveals that a 2.80 mm thick, single-crystal, N-type silicon will transmit nearly 50% of laser output directed at it in a wavelength range of about 1.12 to 4.5 μm when its temperature is between 25 and 300°C. The transmittance of this type of silicon sharply decreases as the wavelength output drops below 1.12 μm.

Fig. 3 is a compilation of the relevant portions of absorbance graphs found in the "Handbook of Laser Science and Technology," Volume IV Optical Materials: Part 2 By Marvin J. Weber, CRC Press, (1986). Fig. 3 shows that metals, such as aluminum, nickel, tungsten, and platinum, absorb usable laser output from a wavelength range from below 0.1 μm to 3.0 μm, with aluminum not absorbing quite so much as the other metals. Metal nitrides (e.g., titanium nitride) and other high conductivity, metal-like materials used to form link structures 12 have generally similar optical absorption characteristics. However, the absorption coefficients for such materials are not as readily available as are those for metals.

The graphs in Figs. 2 and 3 reveal a preferred overlap wavelength range 30 of about 1.2 μm to about 2 μm in which silicon is almost transparent and in which the optical absorption behavior of metal link materials is sufficient for them to be processed. When comparing the

1.2 to 2.0 μm wavelength range 30 to conventional laser wavelengths of 1.064 μm and 0.532 μm, skilled persons will note the optical transmittance of silicon substrate 22 increases by orders of magnitude while the optical absorption of high conductivity link structures 12 decreases by about a factor of two. The contrast between the absorbance, which is typically the inverse of transmittance, of silicon substrate 22 and high conductivity link structures 12 allows utilization of a higher peak power or energy laser pulse 10 to cut link structures 12 without a proportional increase in risk of damaging silicon substrate 22 or adjacent circuit structures 20.

Because shorter wavelengths within the 1.2 μm to 2.0 μm wavelength range 30 provide better laser beam focusability (and hence smaller laser output spots 18), and maximize the absorbance of high conductivity link structures 12, wavelengths such as 1.32 μm and 1.34 μm are preferred for most high conductivity link processing operations. Wavelengths such as 1.32 μm and 1.34 μm are sufficiently long to minimize damage to silicon substrate 22. The choice of 1.32 μm or 1.34 μm is also somewhat predicated on laser source availability and other complexities familiar to those skilled in the art.

In a preferred embodiment, a conventional diode-pumped, solid-state laser with a lasant crystal such as Nd:YAG, Nd:YLF, ND:YAP, or Nd:$YV0_4$ is reconfigured to produce output in the 1.2 to 3.0 μm wavelength range. Each such redesigned laser employs resonator mirrors with appropriate dichroic coatings to be highly transmissive to the most conventional wavelength of the lasant crystal but have desired reflectivity at a selected wavelength within the range 1.2 μm to 3 μm and preferably at 1.32 μm or 1.34 μm. Such dichroic coatings would suppress laser action at

the most conventional wavelength of the lasant crystal, such as 1.06 μm for Nd:YAG, and enhance laser action at the selected wavelength, preferably 1.32 μm for Nd:YAG.

In another preferred embodiment, a diode-pumped or arc lamp-pumped solid-state laser having a lasant crystal of YAG doped with other dopants such as holmium (laser output at 2.1 μm) or erbium (2.94 μm) could be employed to deliver laser output within the 1.2 μm to 3 μm wavelength range.

Preferably, all of the transmissive optics in a delivery path of the laser output beam are antireflection coated for the selected wavelength. In addition, laser output power or energy monitoring devices are changed, for example, from Si for 1.064 μm to Ge or GaAlAs for 1.32 μm or 1.34 μm, to be responsive to the selective wavelength. Other minor optical modifications to compensate for changes in laser output focusing length are preferred and known to those having skill in the art.

One skilled in the art will also recognize that higher output power diode lasers or pumping schemes, such as arc lamp-pumping, may be employed to compensate for the lower gain for lasers with lasant crystals such as Nd:YAG or Nd:YLF at 1.2 μm to 3.0 μm wavelengths. For example, with reference to an embodiment of a laser system 50 shown in Fig. 4, the output (preferably 3.0 watts or greater) of a high-power AlGaAs laser 52 may be funneled along optic axis 54 through a nonimaging concentrator 56 composed of a high refractive index, crystalline dielectric material and then coupled into an Nd:YLF lasant crystal 58. This method is disclosed in copending U.S. patent application No. 07/873,449 of Baird, DeFreez, and Sun, filed April 24, 1992, for Method and Apparatus for Generating and Employing a High Density of Excited Ions in a Lasant, which is assigned to the assignee of the present

invention.

Preferably, laser 52 is positioned against a heat sink 60 and is powered by a diode laser power supply 62 that is controlled by a processing unit 64. Processing unit 64 is also connected to an impedance-matched RF amplifier 66 and controls signals delivered to a transducer coupled to a Q-switch 68. Q-switch 68 is preferably positioned between lasant crystal 58 and an output coupler 70 within a resonator cavity 72. A targeting and focusing system 74 may be employed to direct laser output to a desired position on link structure 12 or other target material. Pumping, Q-switching, and targeting of the laser system 50 of the preferred embodiment are accomplished through conventional techniques well-known to persons skilled in the art.

An input mirror coating 76 on lasant crystal 58 and an output mirror coating 78 on output coupler 70 are preferably highly transmissive at the conventional 1.047 μm YLF emission wavelength. In addition, input mirror coating 76 is transmissive to the AlGaAs emission wavelength range and reflective at about 1.32 μm, and coating 78 is only partly transmissive at 1.32 μm to permit laser operation.

Skilled persons will appreciate that the above-described laser systems can also be employed at wavelengths longer than 1.2 μm to functional process or trim thin film resistor or other structures in active integrated circuit devices. Laser output in the 1.2 μm to 3.0 μm range, for example, can effectively trim resistor material, such as nickel chromide, tantalum nitride, cesium silicide, and other commonly used resistive materials, but does not substantially stimulate undesirable photocurrents on the photodiode or light-sensitive, typically silicon-based, portions of the

devices. As a consequence, no settling time is required between laser trims and the functional measurements of the active devices so the functional measurements can be achieved almost concurrently.

Skilled persons will appreciate that the significant change in the absorption contrast between high conductivity link structures 12 or resistive film structures and the surrounding silicon substrate 22 will allow use of much higher processing powers than could be used with conventional 1.047 μm or 1.064 μm laser systems without causing damage to silicon substrate 22, i.e, the energy of laser output 10 in excess of that used to process high conductivity link structures 12 or resistive film structures will not be absorbed by the underlying silicon substrate 22 during and after the high conductivity link structures 12 or resistive film structures have been processed. The higher power laser output will allow a greater coupling of laser energy into high conductivity link structures 12 or resistive film structures and therefore facilitate a more complete cutting of link structure 12 or trimming of a resistive film structure.

Persons skilled in the art might expect that the level of hole-electron pairs created at the preferred high intensity light level would induce metal-like characteristics in silicon substrate 22, thereby adversely affecting the desired low absorption by silicon substrate 22. Experiments have shown, however, that at the laser power level used, the silicon substrate still retains its low absorption at 1.32 μm.

Higher power laser output may also raise the link or film structure material temperature more quickly and supply enough energy to exceed the required latent heat of vaporization of the link or film material,

therefore resulting in direct vaporization of most or all of the link or film structure material. This direct vaporization is preferred since it will result in little chance of redeposition of the "removed" link or film structure material back onto the surrounding area of the substrate. On the other hand, if the laser power is not high enough due to laser system limitations or due to avoiding the risk of damaging the silicon substrate (as with some conventional link or film processing laser systems), then the direct vaporization rate of the link or film structure material would be much lower. Link or film structure material in the liquid state might then instead be splashed away and redeposited on the surrounding area of the silicon substrate 22 as a conductive "slag" which may cause malfunction of the integrated circuit device.

Preferably, high conductivity link structures 12 or resistive film structures are processed in an oxygen-rich atmosphere to promote the oxidation of the liquid link or film material splashed away (i.e., the "slag"), as well as the very small amount of remaining liquid link or film material in the original link or film position so that they become non-conductive oxides, thereby further reducing the chance of the formation of a conductive bridge over the opened link or short circuit to another part of the integrated circuit, thus improving the yield of the laser processing system. Persons skilled in the art will appreciate that an oxygen concentration sufficient to generate non-conductive slag will vary with the nature of the material processed.

It will be obvious to those having skill in the art that many changes may be made to the details of the above-described embodiments of this invention without departing from the underlying principles thereof. Accordingly, it will be appreciated that this invention is

also applicable to laser-based operations for different semiconductor substrate materials such as germanium, and gallium arsenide, etc., as well as laser-based operations outside the semiconductor industry, for selective removal of one or more materials from a multimaterial device. The scope of the present invention should be determined, therefore, only by the following claims.

Claims

1. A method for selectively processing a multilayer, multimaterial device that includes a substrate and a target structure having respective first and second wavelength sensitive light absorption characteristics, the first and second absorption characteristics having different light absorption properties that provide different light absorption contrasts for different wavelengths of light, comprising:

generating at a predetermined wavelength a laser output having predetermined spatial dimensions; and

directing the laser output to illuminate the target structure, the predetermined wavelength having a value that represents a sufficiently large absorption contrast between the target structure and the substrate to change a physical property of the target structure but leave substantially unchanged the physical property of the substrate within the spatial dimension of the laser output.

2. The method of claim 1 in which the target structure comprises metal and the substrate comprises silicon.

3. The method of claim 1 or claim 2 in which the wavelength of the laser output is in about the 1.2 μm to 3.0 μm range.

4. The method of claim 1 in which the target structure comprises a high conductivity link or a resistive film.

5. The method of claim 1 in which the target structure has a width that is smaller than the spatial dimension of the laser output.

6. The method of claim 2 in which the laser output is directed toward the target structure in an oxygen rich environment.

7. The method of claim 1 in which the target structure comprises multiple layers and the laser output comprises energy in excess of that which is required to process the target structure.

8. The method of claim 1 in which the laser output is generated by a Q-switched, diode-pumped, solid-state laser.

9. The method of claim 3 in which the target structure comprises a metal or combination of metals or metal alloys selected from the group of aluminum, titanium, nickel, copper, tungsten, platinum, gold, nickel chromide, tantalum nitride, titanium nitride, cesium silicide, and the like.

10. A laser system for selectively processing a target structure of a multilayer, multimaterial device including a substrate, the target structure and substrate having wavelength sensitive properties, comprising:

a pumping source; and

a lasant positioned in a resonator cavity adapted to be pumped by the pumping source to provide a laser output having critical dimensions, power, and wavelength selected to exploit differences in the wavelength sensitive properties of the target structure and the substrate such that the target structure within the critical dimensions is effectively processed and the substrate within the critical dimensions is relatively undamaged by the laser output.

11. The laser system of claim 10 in which the target structure comprises metal and the substrate comprises silicon.

12. The laser system of claim 10 or claim 11 in

which the wavelength of the laser output is in about the 1.2 μm to 3.0 μm range.

13. The laser system of claim 11 in which the target structure comprises a high conductivity link or a resistive film.

14. The laser system of claim 10 in which the target structure has a width that is smaller than the critical dimensions of the laser output.

15. The laser system of claim 11 in which the target structure is processed in an oxygen rich environment.

16. The method of claim 12 in which the target structure comprises multiple layers and the laser output comprises energy in excess of that which is required to process the target structure.

17. The laser system of claim 10 further comprising a Q-switched, diode-pumped or arc-lamp pumped, solid-state laser.

18. The laser system of claim 10 in which the lasant is selected from the group of Nd:YAG, Nd:YLF, Nd:YAP, and Nd:YVO_4, and in which the resonator cavity employs resonator mirrors that are highly transmissive to a conventional wavelength of the lasant but have desired reflectivity at a wavelength within a wavelength range of 1.2 to 3.0 μm.

19. The laser system of claim 10 in which the lasant comprises YAG doped with holmium or erbium and the resonator cavity is adapted to generate laser output at a wavelength within a wavelength range of 1.2 to 3.0 μm.

20. A method for employing a laser system to process high conductivity link or resistive film structures formed on a silicon substrate, comprising:

generating laser output in a wavelength range of about 1.2 μm to 3.0 μm; and

directing the laser output at a high conductivity link or resistive film structure such that it is effectively processed but the substrate is relatively undamaged.

21. The method of claim 20 in which the high conductivity link structure has a width, and the laser output has a diameter that is larger than the width of the high conductivity link structure.

22. The method of claim 20 in which the high conductivity link structure comprises a metal or metal alloy.

23. The method of claim 22 in which the high conductivity link structure is processed in an oxygen rich environment.

24. The method of claim 20 in which the high conductivity link structure comprises multiple layers and the laser output comprises energy in excess of that which is required to process the high conductivity link structure.

25. A method for employing a laser system to process a highly conductive material of a target structure formed on a substrate; comprising:

positioning the target structure in an environment having an oxygen concentration;

generating a laser output having energy sufficient to process the material of the target structure; and

directing the laser output to process the target material within the environment, wherein the oxygen concentration is sufficient to substantially convert any slag resulting from processing of the target structure to a substantially non-conductive oxide.

26. The method of claim 25 in which the target material comprises metal and the oxygen concentration is at least 50%.

27. The method of claim 1 in which the target structure comprises a thin film resistor that has a width that is larger than the spatial dimension of the laser output.

28. The laser system of claim 10 in which the target structure comprises a thin film resistor that has a width that is larger than the spatial dimension of the laser output.

29. The method of claim 1 in which the device comprises light-sensitive or photo-electronic portions as part of its circuit and the wavelength of the laser output is in about the 1.2 μm to 3.0 μm range.

30. The method of claim 29 in which the laser beam energy is in excess of that which is required to process the structure without exciting excessive carriers in the substrate or causing malfunction of the light-sensitive or photo-electronic portions.

31. The laser system of claim 10 in which the device comprises light-sensitive or photo-electronic portions as part of its circuit and the wavelength of the laser output is in about the 1.2 μm to 3.0 μm range.

32. The laser system of claim 31 in which the laser beam energy is in excess of that which is required to process the structure without exciting excessive carriers in the substrate or causing malfunction of the light-sensitive or photo-electronic portions.

FIG. 1A
(Prior Art)

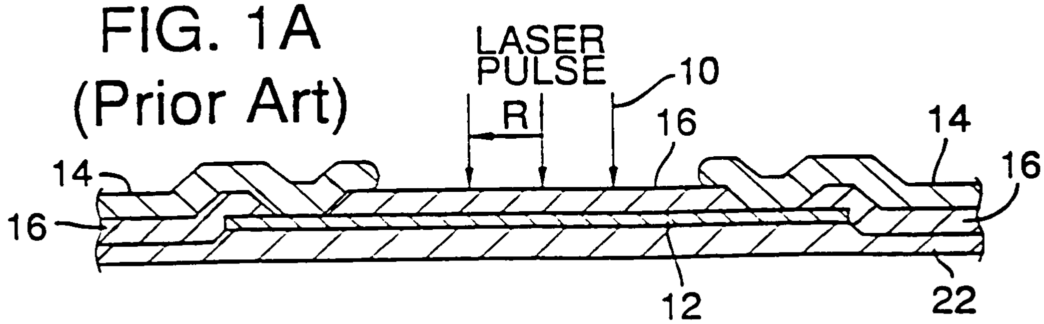


FIG. 1B
(Prior Art)

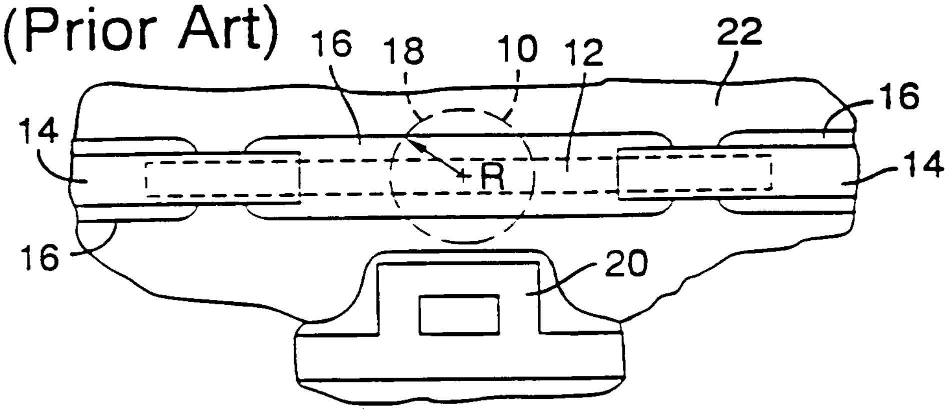


FIG. 2

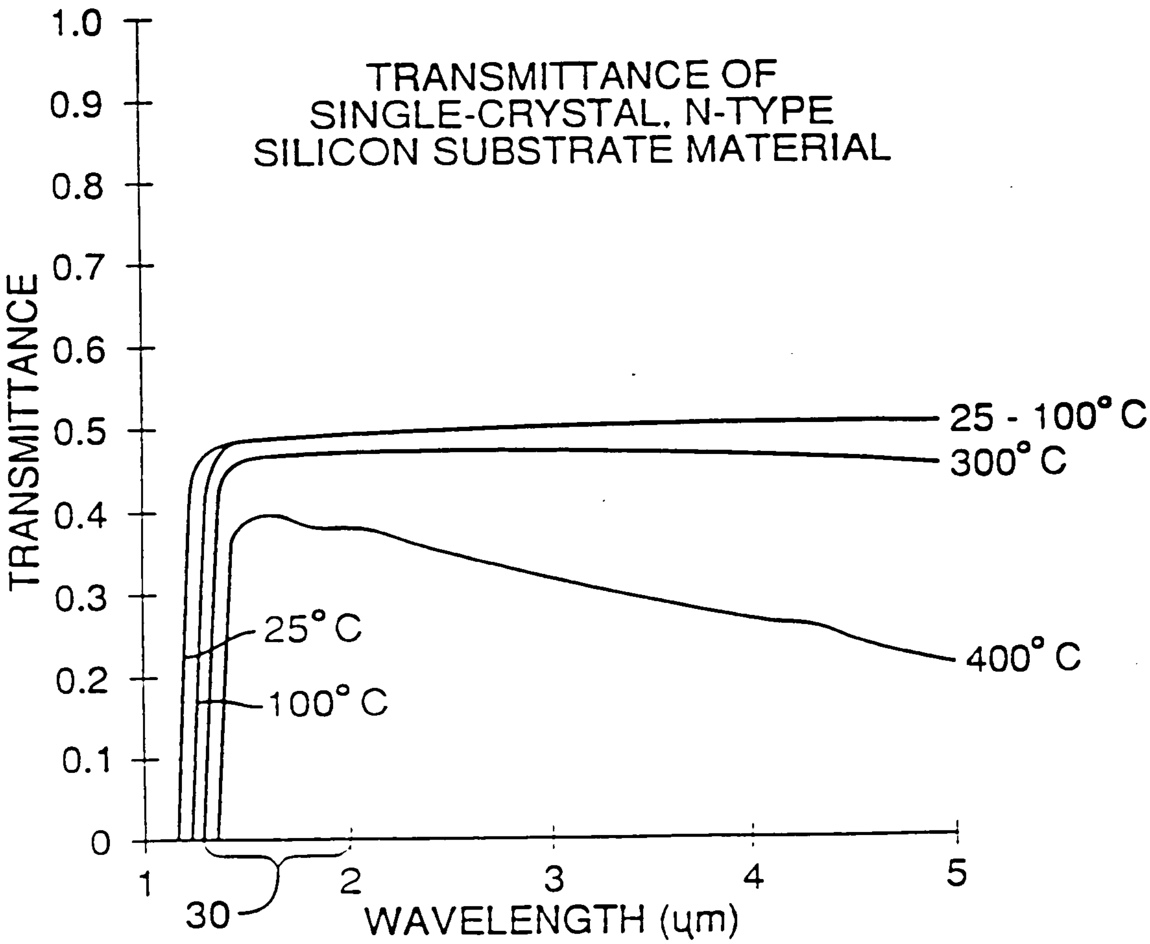


FIG. 3

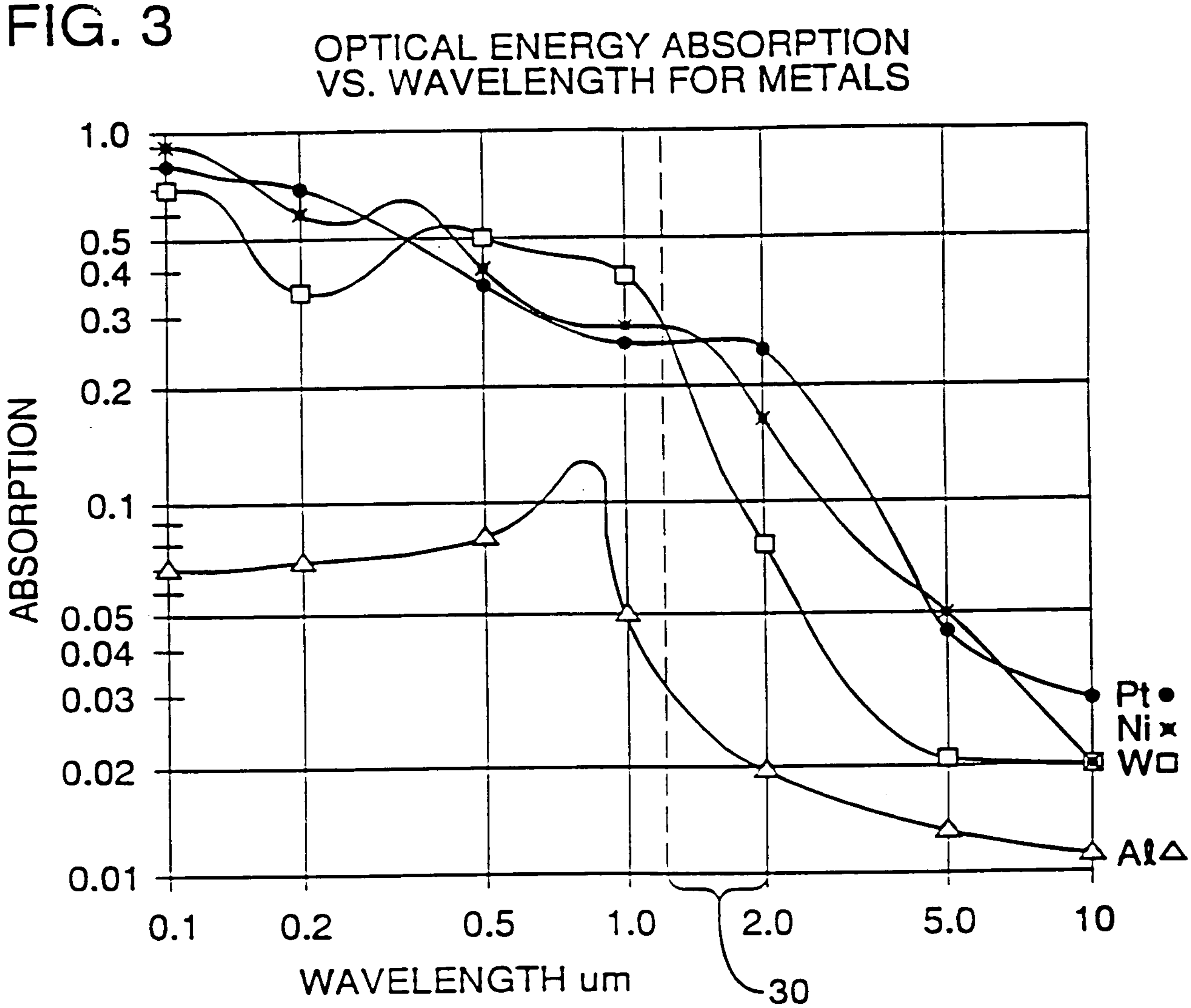
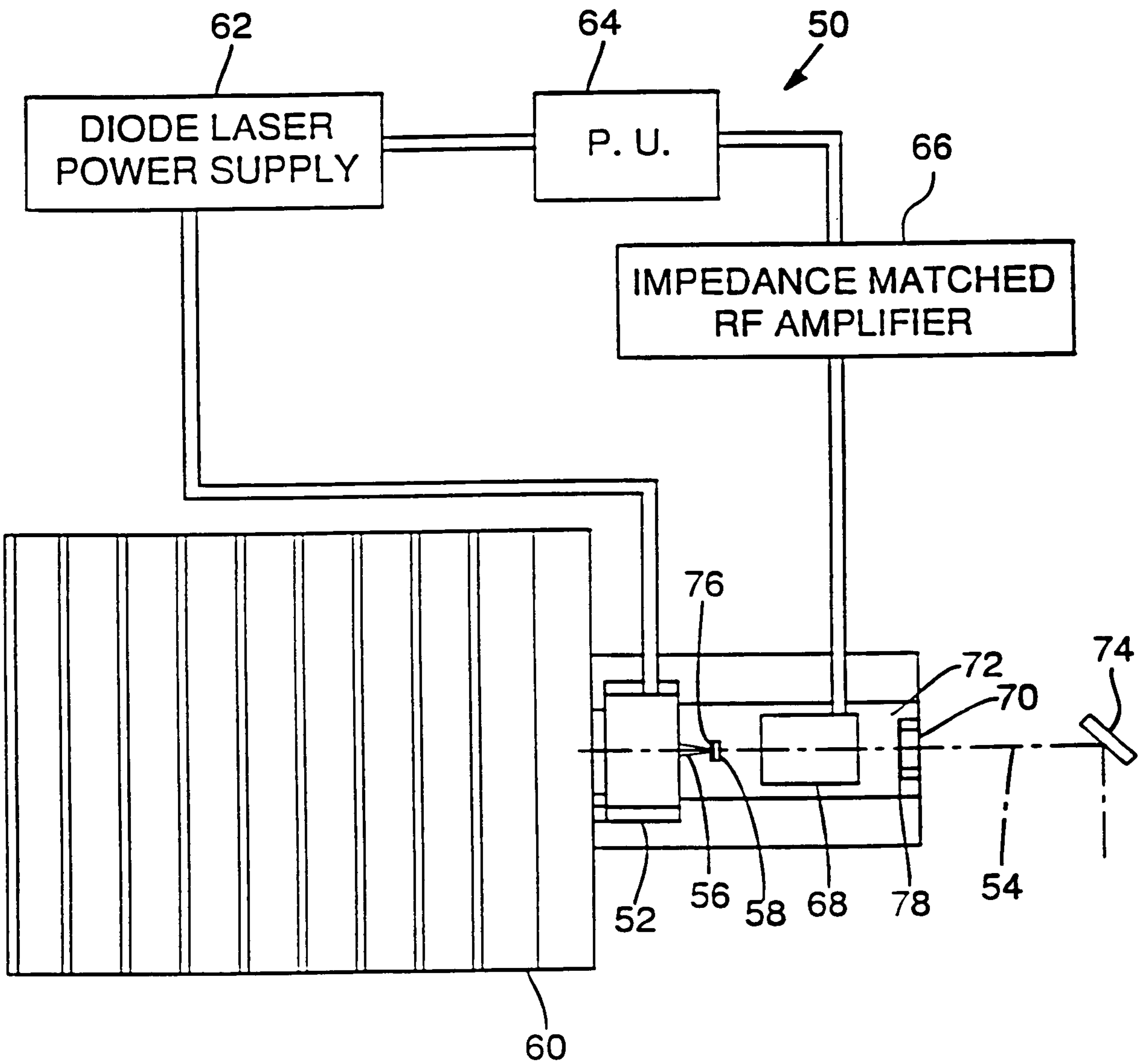

OPTICAL ENERGY ABSORPTION
VS. WAVELENGTH FOR METALS
ABSORPTION
1.0
0.5
0.4
0.3
0.2
0.1
0.05
0.04
0.03
0.02
0.01
0.1
0.2
0.5
1.0
2.0
5.0
10
WAVELENGTH um
30
Pt
Ni
W
Al

FIG. 4


62
64
50
DIODE LASER POWER SUPPLY
P. U.
66
IMPEDANCE MATCHED RF AMPLIFIER
76
74
72
70
52
56
58
68
78
54
60

A. CLASSIFICATION OF SUBJECT MATTER
IPC(5) :HO1S 3/09 US CL :372/69, 70, 71, 72, 75 According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols) U.S. : 372/69, 70, 71, 72, 75
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A. 4,761,786 (Baer) 02 August 1988, see the entire document.	1-32
A	US, A. 4,791,631 (Baumert et al.) 13 December 1988, see the entire dcoument.	1-32
A	US, A. 4,965,803 (Esterowitz et al.) 23 October 1990, see the entire document.	1-32
A,E	US,A. 5,260,963 (Baird et al.) 09 November 1993, see the entire document.	1-32

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be part of particular relevance

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 NOVEMBER 1993	18 NOV 1993
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer For R. BOVERNICK
Facsimile No. NOT APPLICABLE	Telephone No. (703) 308-4883